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TWO FUNGI ASSOCIATED WITH A MICROCYCLIC RUST, COLEOSPORIUM CROWELLII CUMMINS, ON NEEDLES OF PINUS EDULIS ENGELM. IN ARIZONA[1]

Paul D. Keener[2]

The microcyclic rust, *Coleosporium crowellii* Cummins (Cummins, 1938) is unique among species of the genus because of the occurrence of the telial stage on species of *Pinus*. This species of *Coleosporium* is also regarded as autoecious. Other species of *Coleosporium* are macrocyclic with needles of certain pines serving as sites for the pycnia and aecia rather than the telia. In addition, species of *Coleosporium* are generally heteroecious.

Material of *C. crowellii* on *Pinus edulis* Engelm. was collected one mile east of Yaki Point, on the north side of State Highway 64 along the South Rim of the Grand Canyon, Grand Canyon National Park, Coconino County, Arizona, on October 6, 1953. The telial sori were of an unnatural dull yellow-brown, rather than the usual yellow-orange. The sori of the rust fungus were found to be invaded by two non-uredineous fungi, *Darluca filum* (Biv.) Castagne and *Cladosporium aecidiicola* Thüm. Both of the fungi were in their conidial phases. No previous reports of these two hyperparasites on this rust have been found.

Materials for microscopic examination were prepared in the following manner: small portions of pine needle tissue containing rust sori invaded

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by the hyperparasites were placed momentarily in 95 per cent ethyl alcohol, then in lukewarm water for several minutes until softening occurred. Free-hand sections were then prepared. The sections were mounted in 0.25 per cent Orseillin BB in 3 per cent acetic acid and modified Sartory's solution. The Orseillin BB in acetic acid was added to the Sartory's solution (phenol, 10 cc.; lactic acid, 20 cc.; glycerine, 40 cc.; distilled water, 20 cc.) in the proportion of 1 part of the former to 9 parts of the latter. The technique is essentially the same as described by Alcorn and Yeager (1937) with slight modifications including adaptation to free-hand sections.

Darluca filum (Biv.) Castagne

Species of *Darluca* and especially *D. filum* have been reported as associated with numerous rust fungi (*Uredinales*) in many parts of the world. Most of the reports indicate that *D. filum* is more often found in uredinial and telial sori than in aecia. Also, there are more records of the association of this hyperparasite with macro- than with microcyclic rusts. The significant literature concerning the various genera of rusts reportedly susceptible to attack by *D. filum* in various parts of the world has been reviewed (Keener, 1934). In addition, previous investigations involving cross-inoculations with several isolations of *D. filum* from numerous rusts showed that many species of rusts are susceptible to attack by one or more forms of the hyperparasite (Keener, 1934; 1952). Isolations of *D. filum* from infected rusts in the field, cultured on "Difco" Lima Bean agar, were used as sources of inocula in the previous studies (Keener, 1933; 1934). The studies confirmed the fact that both macro- and microcyclic rusts are susceptible to attack by *D. filum,* if suitable environmental conditions prevail. Although not previously emphasized (Keener, 1934) it was found that no great morphological differences existed among the various isolations of *D. filum* from field-infected materials, and the same isolates after inoculations on rusts other than those from which they originated. The same was true of isolations of the hyperparasite from field-infected materials when inoculated in the greenhouse onto rusts similar to those from which they had been isolated.

The fungus found inhabiting telial sori of *Coleosporium crowellii* at Grand Canyon agrees in most morphological respects with the isolations of *D. filum* from various rusts studied previously (Keener, 1934). Some interesting differences were noted. In most cases previously recorded, pycnidia of the hyperparasite have been described as being superficial with respect to the area occupied by the rust sorus. In the Grand Canyon material of *D. filum* on *C. crowellii* this was not always true. Many of the pycnidia of *D. filum* were found at the bases of the telial columns of the rust, in close association with the basal teliospores (fig. 1). Since the basal teliospores themselves are actually embedded in the pine needle mesophyll, the pycnidia of *D. filum* are frequently invisible in the field even with the aid of a hand lens. Only at certain stages were pycnidia of the hyperparasite observed in the telial columns at a level with the needle

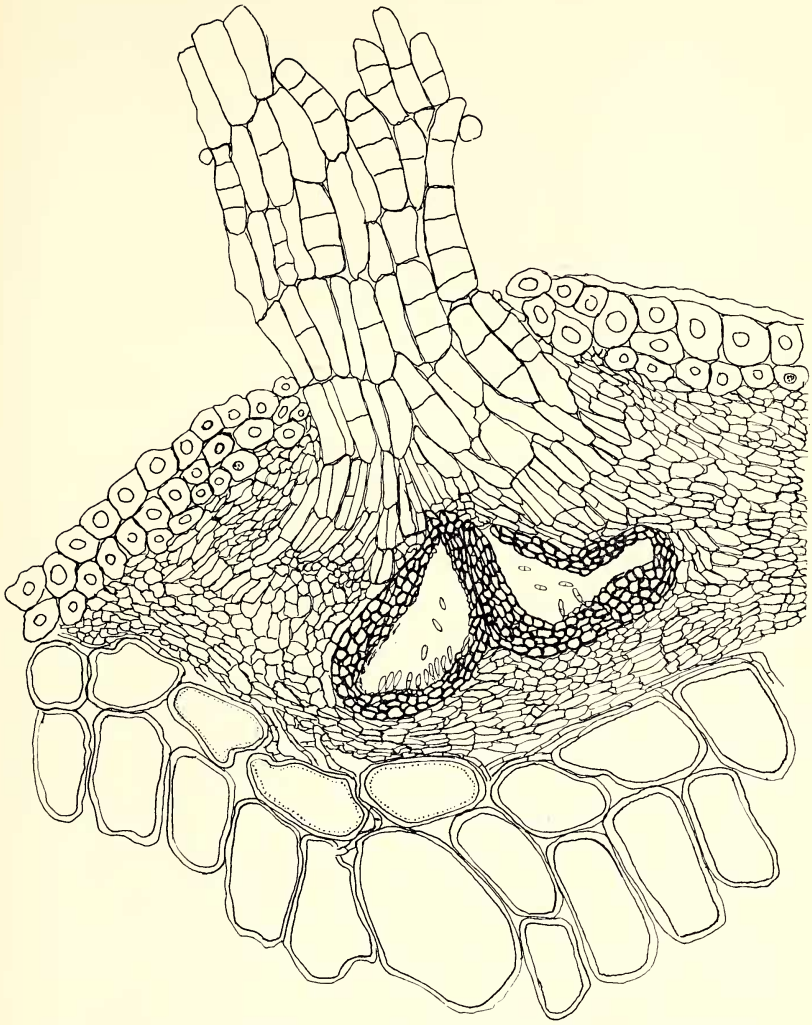

FIG. 1. Schematic representation showing two pycnidia of *Darluca filum* associated with basal teliospores in the telial column of *Coleosporium crowellii*. Magnification approximately × 270.

epidermis or above. The invisibility of the pycnidia prevails until after the collapse of the telial column, at which time they may be observed to be superficial with respect to the rust sorus and the pine needle tissues. The invisibility of the pycnidia for considerable periods of time may account in part for the absence of any previous reports of *D. filum* associated with *C. crowellii*.

A peculiar feature of the invasion of telial sori of *C. crowellii* by *D. filum* is the manner in which the long, twisted, dark-brown, fragile spore threads of the hyperparasite reach the needle surface. These threads issue

from the region between the bases of the telial columns and the ruptured pine needle epidermis (fig. 2, B). The threads contain the typical 2–3-celled macroconidia of *D. filum* (fig. 3, A). Some of the fragility may be

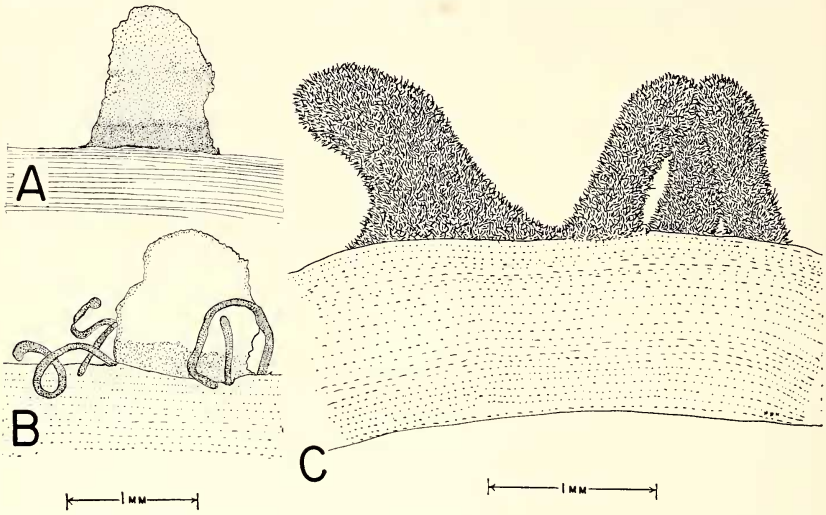

FIG. 2. Schematic drawings of telial columns of *Coleosporium crowellii* with associated fungi on needles of *Pinus edulis*. A. Telial sorus free of any invasion by hyperparasitic fungi. B. Spore threads of the hyperparasite, *Darluca filum,* issuing from between the pine needle epidermis and the base of the rust telial column. C. Conidiophores and other fungus structures of *Cladosporium aecidiicola* completely overrunning telia of the rust.

due to the prevailing dry atmosphere in Arizona. In spite of the desiccation of the spore threads, macroconidia germinated readily in sterile distilled water on glass slides in from 4–6 hours at room temperatures. Often the spore threads which are best observed with a dissecting microscope are the only visible evidence of rust sorus invasion. Non-invaded sori show no thread-like strands (fig. 2, A).

CLADOSPORIUM AECIDIICOLA Thüm.

Parasitism of rust fungi by species of *Cladosporium* has been reported in the past chiefly from the continent of Europe and the region of the Mediterranean. Some of the pertinent literature has already been reviewed (Keener, 1954). Of interest are two previous reports of this hyperparasite of rusts from the western United States (Keener, 1954; Smith, 1905).

In the Grand Canyon material of *Coleosporium crowellii* invaded by *Cladosporium aecidiicola* no preference by the hyperparasite for a particular region of the rust telial column was noted. The brown, septate hyphae and 1–2-celled yellow-brown conidia of *C. aecidiicola* (fig. 3, B), appeared to inhabit all parts of the telial sorus, frequently overrunning the entire column (figs. 2, C; 4). The telial columns inhabited by the

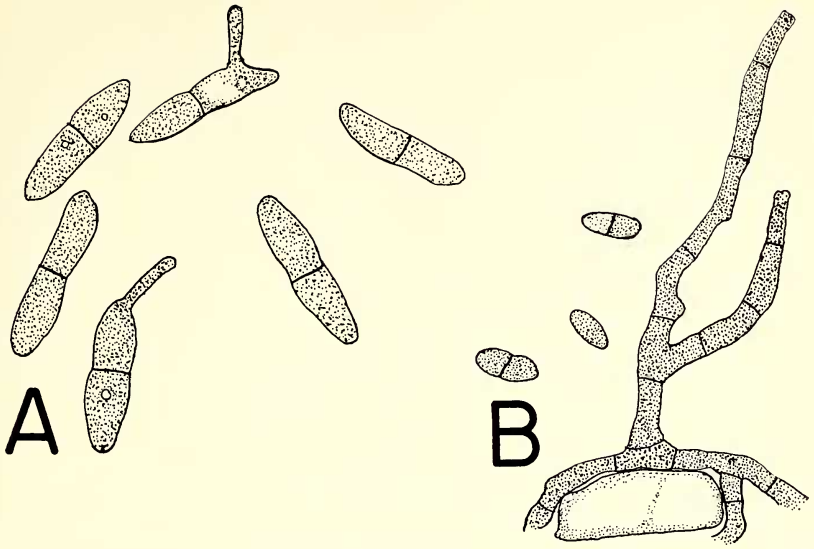

FIG. 3. Fungus structures of two hyperparasites associated with telial sori of the microcyclic rust, *Coleosporium crowellii* on *Pinus edulis*. A. Macroconidia, two of which show germ tubes, of *Darluca filum*. B. Conidiophores and conidia of *Cladosporium aecidiicola*. Magnification approximately × 300.

hyperparasite were dark-brown to black rather than the dull yellow-brown color of sori inhabited by *D. filum*. Due to their dark color, telial sori of *Coleosporium crowellii* inhabited by *Cladosporium aecidiicola* are easily recognized in the field, their pigmentation contrasting strikingly with the yellow-orange color of non-invaded ones. Sori invaded by *C. aecidiicola* appear to collapse sooner and more completely than do those attacked by *D. filum*. This is probably due to the complete invasion of the entire telial column of the rust by *C. aecidiicola*.

The morphological features of the fungus referred to as *C. aecidiicola*

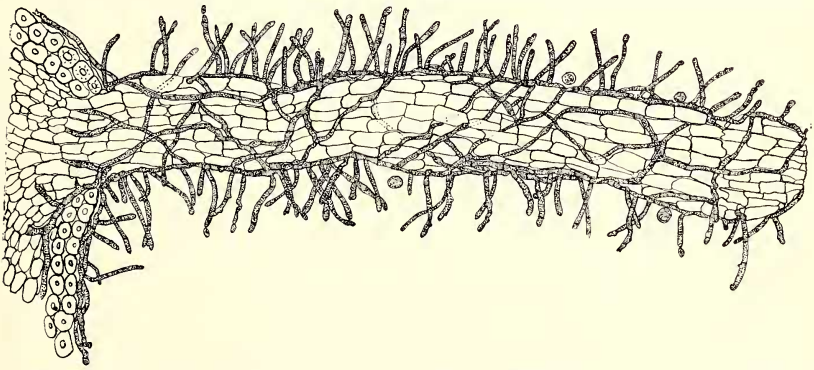

FIG. 4. Diagrammatic drawing showing a single telial column of the microcyclic rust, *Coleosporium crowellii* on *Pinus edulis*, completely invaded and overrun by the vegetative hyphae of the hyperparasite, *Cladosporium aecidiicola*. Magnification ×38.

agree with those described for this species by other authors as well as with those of a similar fungus found inhabiting aecial sori of *Puccinia conspicua* (Arth.) Mains on *Helenium hoopesii* A. Gray in southern Arizona (Keener, 1954).

In October 1954, over forty specimens of *Pinus edulis* with needles on the lower branches attacked by *Coleosporium crowellii* were observed within the boundaries of Grand Canyon National Park, in the vicinity of Yaki and Moran Points. In spite of the below average rainfall during the preceding months, *Cladosporium aecidiicola* was widespread in many of the telial sori of the rust. This hyperparasite appeared to be more generally distributed in sori of *Coleosporium crowellii* than was *D. filum*. In 1954, *D. filum* was virtually absent in the Grand Canyon area on *C. crowellii*. Recently material of *Cladosporium aecidiicola* has been noted in aecial sori of *Cronartium quercuum* (Berk.) Miyabe on cones of *Pinus cembroides* Zucc. The hyperparasite has been isolated into pure culture from this material.

One specimen of *Pinus edulis* was found at Grand Canyon which had sori of *Coleosporium crowellii* invaded by *Cladosporium aecidiicola* and on the same or on different needles, fruiting bodies (hysterothecia) of *Elytroderma deformans* (Weir) Darker. The latter fungus is an Ascomycete and causes a needle-cast of conifers.

The assistance in securing permission to collect the necessary materials as well as the continued interest in the study profered by Mr. Louis Schellbach, Park Naturalist for Grand Canyon National Park, is hereby gratefully acknowledged.

Summary

1. Association of the hyperparasites, *Darluca filum* (Biv.) Castagne and *Cladosporium aecidiicola* Thüm. with telial sori of the microcyclic rust, *Coleosporium crowellii* Cummins on *Pinus edulis* Engelm., is reported for the first time.

2. Morphological similarities and differences between these associations and similar though not identical ones recorded previously are discussed.

3. The investigation is based on materials collected in the vicinity of Yaki and Moran Points, South Rim of the Grand Canyon, Grand Canyon National Park, Coconino County, Arizona.

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A NATURAL HYBRID, × ADIANTUM TRACYI C. C. HALL[1]

Warren H. Wagner, Jr.

A plant intermediate between the two common maidenhair ferns of California, *Adiantum jordanii* K. Müll. and *A. pedatum* L., was first discovered over a half-century ago, but except for several brief references in British gardeners' publications (Stansfield, 1927; Macself, 1947; Logan, 1948), notes on it have never been published. The intermediate plant has now become established in horticulture both in California and in England, and is notable for its vigorous growth. Although the spores of this fern appear to be inviable, the rhizomes are capable of bearing numerous lateral shoots, enabling single plants to form large patches in gardens and to be readily propagated.

The fact that the plant described here is evidently intermediate between *A. jordanii* and *A. pedatum* in its obvious features is a strong point in favor of interpreting it as a hybrid between them. This conclusion is also supported by the following facts: the intermediate plant is rare and sporadic in distribution as compared with the much more abundant and widespread parents, and it has been found wild in only three counties of California; the supposed parents were present in the immediate vicinity of the putative hybrid; the sporangia of the intermediate are abortive and its spores are of irregular sizes and shapes. With such evidence indicative of hybrid origin I believe that it would be erroneous to name and describe this fern as a normal taxonomic species.

At the present time I know of only ten places where this plant is in cultivation but there are probably many more. In view of its luxuriant growth and graceful appearance it is likely to become widely distributed in horticulture. For this reason the information that has been gathered on the history of its discovery and spread in horticulture should be useful.

The intermediate fern was first found in September, 1895, by the late Joseph Prince Tracy, a well-known botanist of Eureka, California, whose

[1] Study made during the tenure of a Summer Faculty Research Fellowship of the Horace H. Rackham School, University of Michigan.